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Information Extraction and Exclusivity

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1 Introduction

Much analysis has been recently devoted in the contract literature to economies in which each agent observes a signal about other agents' private information. This toghether with correlation among agents' outputs may be used to design information extraction mechanisms. In some cases it can be shown that the optimal contract implements full information extraction, and hence the incentive constrained optimum coincides with the Pareto optimum.

We study the robustness of information extraction mechanism with respect to economies in which 'exclusive' contracts cannot be implemented. By this we mean situations in which a 'principal' or a financial intermediary cannot observe, monitor or contract upon all the contractual relationships an agent may enter with other intermediaries or agents. This is a very plausible situation if we think of informal or implicit contracts that are not in general publicly observable. In a previous paper (Bisin and Guaitoli 1998) we analyzed equilibria with moral hazard and financial intermediaries competing in a 'non-exclusivity' environment, showing that equilibria are never second best efficient and very often fail to implement the optimal action. It is interesting to ask, therefore, whether information extraction in groups of agents may overcome the serious inefficiency generated by non-exclusivity.

The simplest environment to pursue this analysis consists of an hidden action economy in which: i) agents are organized in pre-specified groups of two individuals (e.g. a firm); ii) the outputs of agents in the same group are correlated; iii) agents in any group perfectly observe each other effort. The incentive problem consists in extracting from any agent information about the effort of the other agent in his group (which only he observes). This must be done via contracts contingent on the observable realizations of both agents and their reports.

In such environments we can show that full information extraction is never sustainable at an equilibrium with non-exclusivity, while information is fully extracted at the incentive constrained optimum, which for these economies coincides with the (first best) Pareto optimum.

A contract which fully extracts information in an economy as above described can be constructed as follows. Suppose the contract designer can ask each agent to send a message about the effort of the other agent in his group. If contract payoffs can be found so that each agent has an incentive to tell the truth (i.e. to report low effort on the other agent if and only if he actually observed low effort, and viceversa for high effort), then full information is extracted and contracts can be effectively made contingent on effort for each agents (indirectly via the other agent's message). Each agent will then choose the Pareto optimal effort as if his effort were publicly observed. Note that rewards for the truthful reporting of the low action of the other agent in the group are never paid by the intermediary in equilibrium since both agents choose the high effort. Finally, a contract with payoffs that guarantee truth telling in the agents' message game can be found provided the outcome of each agent depends enough from the other agent's effort as well as from its own.

The contract which implements full extraction just described is not sustainable though in equilibrium if it cannot be effectively made exclusive. The argument is as follows. Suppose an intermediary issued this contract. Then there exists a contract (the 'deviating' contract) that acts as a pre-commitment on the part of both agents never to report the other's low effort. By entering both this contract and the (full information extraction) optimal contract agents are able to choose the low effort (without being caught), and hence to enjoy full insurance at a (better than fair) price, while saving on the effort cost. As a consequence the 'deviating' contract makes non-negative profits, while the (full information extraction) optimal contract makes negative profits.

The 'deviating' contract is constructed essentially to insure an agent against the possibility of being reported (by the other agent) as having chosen low effort, and to punish an agent for revealing the low effort choice of the other. This type of contracts looks like a social norm which punishes for 'informing' on the other members of the group, independently of their actions. These forms of social norms fit quite well with non-exclusivity environments (since obviously the adoption of a norm is very difficult to monitor), and are quite common e.g. among extended family members, among members of various social, religious or intellectual groups, etc.. We argue therefore that social norms could be studied as implicit, informal contracts in environment characterized by non-exclusivity.

Within the related literature, we refer in particular to Ma (1988), where he suggests a mechanism to implement the first best in a similar economy. Our first proposition replicates his conclusion but through a different mechanism, providing therefore a different proof of the result. For the non-exclusive case, Holmstrom and Milgrom (1990) discuss the consequences of unregulated trade among agents but in a context where agents collude and choose jointly their effort as a syndicate. What we have in our model is not collusion, but non-cooperative Nash equilibrium choices of both effort and 'side-contracts'.

2 The economy

More specifically the economy we study is as follows. It is a hidden action economy which lasts two periods, $t \in \{0, 1\}$; agents' preferences value consumption in period 1 only: $u_1(c_1) - v(e)$; and effort is private information. Also, effort can take two values, $e \in \{a, b\}$, with $v(a) > v(b)$. Agent i's endowment w_1^i takes values w_H, w_L, with $w_H > w_L$. Agents are grouped in couples $(i, X(i))$ (X is a one-to-one and onto map[1]). The probability distribution of agent i's endowment is affected by both i's and $X(i)$'s effort: $\pi_{e^i, e^{X(i)}}(s^i)$, for $s^i \in \{H, L\}$. We denote with $\pi_{e,e'} = \pi_{e,e'}(H)$ the probability that agent i has the high endowment H, given that he chose effort e and $X(i)$ choose effort e' (note that $\pi_{e,e'}$ refers to agent i's probability, even though the index i does

[1] Agent i and $X(i)$ are symmetric. For simplicity we report the notation only for agent i.

not appear in the notation). Agent i receives a private information signal which fully reveals $e^{X(i)}$ (and symmetrically for agent $X(i)$). Agent i then sends a message m^i with value in $\{a, b\}$ about $e^{X(i)}$ (and symmetrically for agent $X(i)$). Finally, contract j's payoff to agent i is denoted $d^j = \{d^j_{H,m^i,m^{X(i)}}, d^j_{L,m^i,m^{X(i)}}\}$. Note that contracts only pay off in period 1 (since agents only consume in period 1) and depend on agents' messages regarding their partner's effort.[2]

3 Information extraction

We are now ready to characterize the incentive constrained optimum for the information extraction economy when exclusive contracts can be implemented.

Proposition 1 *In the information extraction economy with exclusivity, assume*

$$\frac{(1-\pi_{aa})}{\pi_{aa}} < \frac{(1-\pi_{ba})}{\pi_{ba}} < \frac{(1-\pi_{ab})}{\pi_{ab}} < \frac{(1-\pi_{bb})}{\pi_{bb}}. \tag{1}$$

Then the incentive constrained optimal allocation is unique and achieves the Pareto optimum:

$$c_H = c_L = \pi_E w_H + (1-\pi_E) w_L$$

where $E \in \{a, b\}$ is the effort choice at the Pareto optimum.

Proof. See Appendix.[3]

The contracts $\{d_{sE}\}_{s\in S,\, E\in\{a,b\}^2}$ which implement the Pareto optimum must extract information on e^i from $X(i)$, for any $i \in I$; hence the dependence of the contract payoff on the messages is non trivial: $d_{s,E} \neq d_{s,E'}$, $\forall s \in \{H, L\},\ E,\ E' \in \{a, b\}^2$.

The proof of Proposition 1 constructs a contract which implements full information extraction (the only non-trivial case is when at the Pareto optimum both agent choose the high effort, $E = (a, a)$). This contract has the property that it rewards agent i for truthfully reporting agent $X(i)$'s low effort (and viceversa). In equilibrium then full information is extracted and, as a consequence, agents choose the high effort and are provided with full insurance contracts at fair price, $(1-\pi_{aa})/\pi_{aa}$. Condition (1) guarantees that a contract which pays agent i a positive amount in expected value

[2]In general payoffs should be allowed to depend also on the partner's realized outcome, as in 'relative performance evaluation' models (cf. Hart-Holmstrom (1987)). Here we omit it for simplicity, since (as we prove) it is not needed for the optimal contract to reach the first best (Proposition 1), while it would not change qualitatively the main consequence of non-exclusivity, i.e. the impossibility of full information extraction (Proposition 2).

[3]Ma (1988) shows that full information extraction is the unique Perfect Nash Equilibrium of the optimal contract problem, allowing for general implementation mechanisms (e.g. sequential mechanisms). Proposition 1 is a stronger result because it proves Subgame Perfect Implementation via simultaneous mechanisms (a subset of the mechanisms allowed in Ma (1988)).

when $X(i)$ has chosen the low effort, and a negative expected amount when $X(i)$ has chosen the high effort, does in fact exists. Moreover the reward for truthful reporting the low action of the other agent in the group is never paid by the intermediary in equilibrium since both agents choose the high effort.

4 Non-exclusive contracts

We now consider the information extraction economy when exclusivity cannot be imposed on contracts. This will be the case whenever the principal is unable to monitor agents' trades with other intermediaries or among themselves, or even when information about such trades is not verifiable.

Proposition 2 shows though that there exists a contract (which we construct in the proof) that acts as a pre-commitment on the part of both i and $X(i)$ to never report the other's low effort. By entering both this contract and the incentive constrained optimal contract agents are able to choose the low effort (without being caught), and hence to enjoy full insurance at the (better than fair) price $(1-\pi_{aa})/\pi_{aa}$, while saving on the effort cost.

Referring to the contract which implements the Pareto optimum (cf. proof of Proposition 1) as contract d, we have the following result.

Proposition 2 *In the information extraction economy with non-exclusivity, assume condition (1) and $E = (a, a)$ at the Pareto optimum. There exists then a contract d' such that if the set of contracts $\{d, d'\}$ is issued:*

- *all agents buy both contracts*
- *all agents choose the low effort, i.e.* $(e^i, e^{X(i)}) = (b, b)$
- *each agent i reports the high effort for agent $X(i)$ and viceversa, i.e.* $(m^i, m^{X(i)}) = (a, a)$.

Proof. See Appendix.

Whenever contracts d and d' are simultaneously issued, then, the intermediary issuing the incentive constrained optimal contract d will make negative profits, while the intermediary issuing contract d' will make zero profits (d' can obviously be perturbed to generate small positive profits).

Contract d' essentially insures agent i against the possibility that agent $X(i)$ reveals that he has chosen low effort, and punishes agent i for revealing the low effort choice of $X(i)$ (and viceversa).

It is also clear from the proof that contracts of the form of d' can be constructed to upset any base contract designed to extract information by agent i on agent $X(i)$'s effort.

References

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Appendix

Proof of Proposition 1. The proof is by construction of an optimal contract d (we concentrate on the only non-trivial case in which, at the Pareto optimum, $E = (a, a)$). Take $d_{s,a,a} = d_s^{FI}$, $\forall s \in S$, such that

$$w_H + d_H^{FI} = w_L + d_L^{FI} \quad \text{and} \quad \pi_{a,a} d_H^{FI} + (1 - \pi_{a,a}) d_L^{FI} = 0$$

i.e. d_s^{FI} are the payoffs associated with the (full insurance) Pareto optimal contract. Also take $d_{s,a,b} = d_s^{FI} - P$, $d_{s,b,a} = d_s^{FI} + \hat{d}_s$, $d_{s,b,b} = d_s^{FI} + \hat{d}_s - P$, where $\hat{d} = (\hat{d}_H, \hat{d}_L)$ satisfies:

$$\begin{aligned}
\pi_{a,a} u^i(w_H + d_H^{FI} + \hat{d}_H) + (1 - \pi_{a,a}) u^i(w_L + d_L^{FI} + \hat{d}_L) &= U^{FI} - \epsilon_{a,a} \\
\pi_{a,b} u^i(w_H + d_H^{FI} + \hat{d}_H) + (1 - \pi_{a,b}) u^i(w_L + d_L^{FI} + \hat{d}_L) &= U^{FI} + \epsilon_{a,b} \\
\pi_{b,a} u^i(w_H + d_H^{FI} + \hat{d}_H) + (1 - \pi_{b,a}) u^i(w_L + d_L^{FI} + \hat{d}_L) &= U^{FI} - \epsilon_{b,a} \\
\pi_{b,b} u^i(w_H + d_H^{FI} + \hat{d}_H) + (1 - \pi_{b,b}) u^i(w_L + d_L^{FI} + \hat{d}_L) &= U^{FI} + \epsilon_{b,b}
\end{aligned}$$

with $\epsilon_{hk} > 0$, $h, k \in \{a, b\}$; and $U^{FI} = u^i(w_H + d_H^{FI}) = u^i(w_L + d_L^{FI})$. A sufficient condition for $\hat{d}$ to exist (i.e. for the equations above to be satisfied) is

$$\frac{(1 - \pi_{a,a})}{\pi_{a,a}} < \frac{(1 - \pi_{b,a})}{\pi_{b,a}} < \frac{(1 - \pi_{a,b})}{\pi_{a,b}} < \frac{(1 - \pi_{b,b})}{\pi_{b,b}}$$

(construct $\hat{d}$ to have negative expected value if $(e, e) = (a, a)$ or if $(e, e) = (b, a)$, and positive expected value if $(e, e) = (a, b)$ or $(e, e) = (b, b)$). For $\hat{d}$ small enough there exist then $\omega_{hk} > 0$, $h, k \in \{a, b\}$, such that with messages (b, b)

$$\begin{aligned}
\pi_{a,a} u^i(w_H + d_H^{FI} + \hat{d}_H - P) + (1 - \pi_{a,a}) u^i(w_L + d_L^{FI} + \hat{d}_L - P) &= U^P - \omega_{a,a} \\
\pi_{a,b} u^i(w_H + d_H^{FI} + \hat{d}_H - P) + (1 - \pi_{a,b}) u^i(w_L + d_L^{FI} + \hat{d}_L - P) &= U^P + \omega_{a,b} \\
\pi_{b,a} u^i(w_H + d_H^{FI} + \hat{d}_H - P) + (1 - \pi_{b,a}) u^i(w_L + d_L^{FI} + \hat{d}_L - P) &= U^P - \omega_{b,a} \\
\pi_{b,b} u^i(w_H + d_H^{FI} + \hat{d}_H - P) + (1 - \pi_{b,b}) u^i(w_L + d_L^{FI} + \hat{d}_L - P) &= U^P + \omega_{b,b}
\end{aligned}$$

with $U^P = u^i(w_H + d_H^{FI} - P) = u^i(w_L + d_L^{FI} - P)$.

We do not need to impose market clearing conditions on $\hat{d}$ since in equilibrium, we will show that, given d, $E = (e^i, e^{X(i)}) = (a, a)$. The game played by agents is represented in Figure 1.

< Figure 1 >

The reader can check that, proceeding by backward induction, the unique Nash Equilibria of the four simultaneous last-stage games (i.e. the message games) are respectively

$$(a, a);\ (b, a);\ (a, b);\ (b, b).$$

We can then construct the first stage simultaneous game's payoff matrix:

< Figure 2 >

whose Nash Equilibrium is $(e^i, e^{X(i)}) = (a,a)$, for P large enough. $\diamondsuit$

Proof of Proposition 2. The proof is by construction. Take a contract d' as follows: $d'_{s,e,e'} = \tilde{d}_s + d''_{s,e,e'}$, with $\tilde{d}_s$ such that $\hat{d}_s + \tilde{d}_s = 0$, $\forall s$. Also $d''_{s,e,e'}$ satisfies: $d''_{s,a,a} = d''_{s,a,b} = 0$, and $d''_{s,b,a} = d''_{s,b,b} = d''_s$ such that

$$\begin{aligned}
\pi_{a,a} u^i(w_H + d_H^{FI} + d''_H) + (1-\pi_{a,a}) u^i(w_L + d_L^{FI} + d''_L) &= U^{FI} + \delta_{a,a} \\
\pi_{a,b} u^i(w_H + d_H^{FI} + d''_H) + (1-\pi_{a,b}) u^i(w_L + d_L^{FI} + d''_L) &= U^{FI} + \delta_{a,b} \\
\pi_{b,a} u^i(w_H + d_H^{FI} + d''_H) + (1-\pi_{b,a}) u^i(w_L + d_L^{FI} + d''_L) &= U^{FI} + \delta_{b,a} \\
\pi_{b,b} u^i(w_H + d_H^{FI} + d''_H) + (1-\pi_{b,b}) u^i(w_L + d_L^{FI} + d''_L) &= U^{FI} - \delta_{b,b}.
\end{aligned}$$

Again, such a contract d''_s exists if

$$\frac{(1-\pi_{a,a})}{\pi_{a,a}} < \frac{(1-\pi_{b,a})}{\pi_{b,a}} < \frac{(1-\pi_{a,b})}{\pi_{a,b}} < \frac{(1-\pi_{b,b})}{\pi_{b,b}}.$$

Again, for d''_s small enough there exist $\gamma_{hk} > 0$, $h, k \in \{a, b\}$, such that

$$\begin{aligned}
\pi_{a,a} u^i(w_H + d_H^{FI} + d''_H - P) + (1-\pi_{a,a}) u^i(w_L + d_L^{FI} + d''_L - P) &= U^P + \gamma_{a,a} \\
\pi_{a,b} u^i(w_H + d_H^{FI} + d''_H - P) + (1-\pi_{a,b}) u^i(w_L + d_L^{FI} + d''_L - P) &= U^P + \gamma_{a,b} \\
\pi_{b,a} u^i(w_H + d_H^{FI} + d''_H - P) + (1-\pi_{b,a}) u^i(w_L + d_L^{FI} + d''_L - P) &= U^P + \gamma_{b,a} \\
\pi_{b,b} u^i(w_H + d_H^{FI} + d''_H - P) + (1-\pi_{b,b}) u^i(w_L + d_L^{FI} + d''_L - P) &= U^P - \gamma_{b,b}.
\end{aligned}$$

We can then follow the steps of the proof of Proposition 1 to show the following. If both agents $(i, X(i))$ buy both contracts (d, d') (see the game in Figure 3, then in equilibrium $(e^i, e^{X(i)}) = (b, b)$.

< Figure 3 >

Similarly, it can be shown that if only agent i buys both contracts (d, d'), while agent $X(i)$ buys d, then in equilibrium $(e^i, e^{X(i)}) = (a, b)$. If only agent $X(i)$ buys both contracts (d, d'), while agent i buys d, then in equilibrium $(e^i, e^{X(i)}) = (b, a)$.

The portfolio choice is determined by the Nash equilibrium of the following game:

< Figure 4 >

Hence both agents $(i, X(i))$ buy both contracts (d, d') and play $(e^i, e^{X(i)}) = (b, b)$ (note that in equilibrium the intermediary issuing contract d' has zero profits). $\diamondsuit$